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THE RADIO DROGUE SYSTEM

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THE RADIO DROGUE SYSTEM

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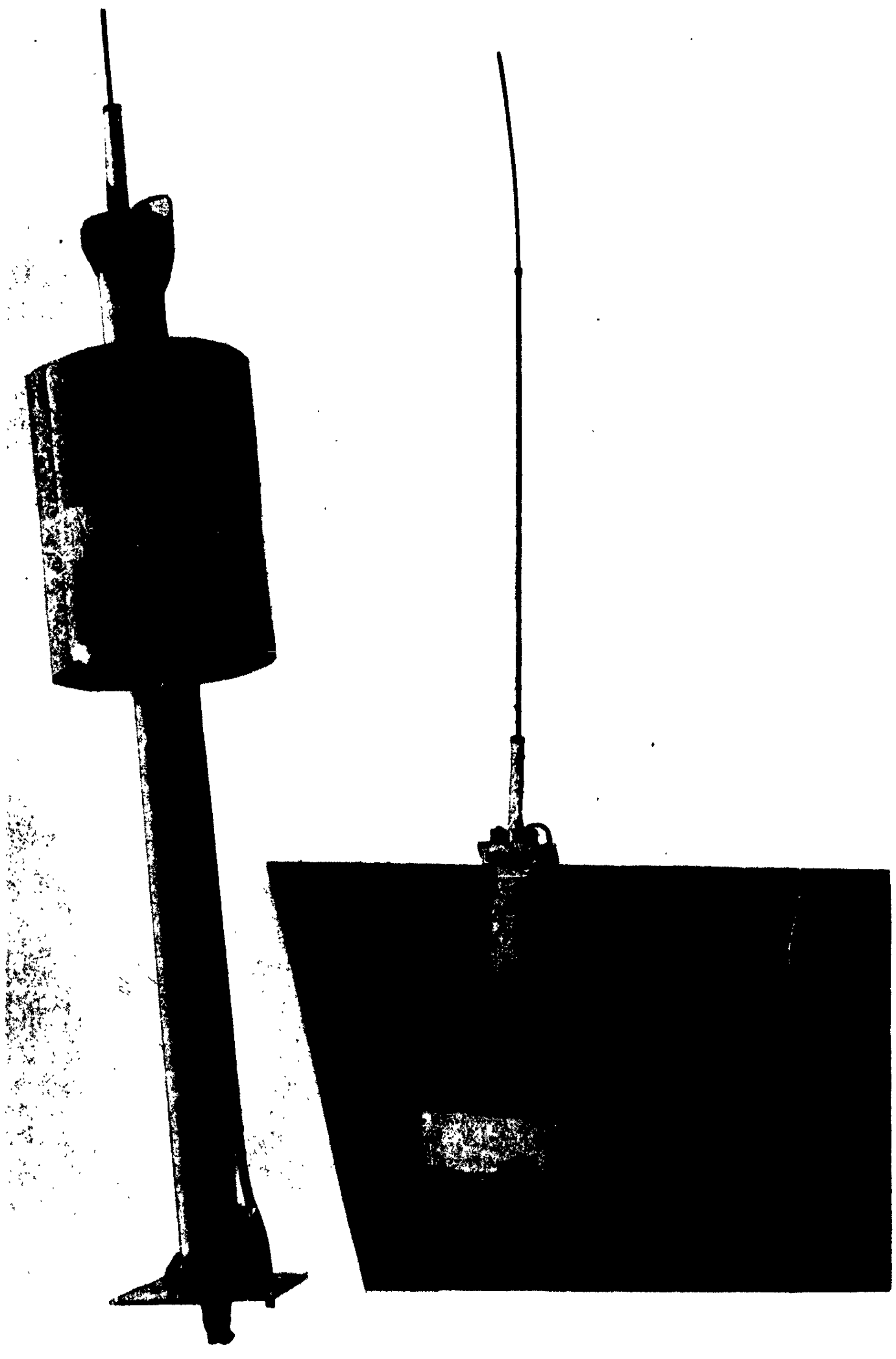

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ABSTRACT

During the period between June 1961 and June 1962, a successful system was developed at Woods Hole Oceanographic Institution for directly measuring deep ocean currents covering many months of time. The incorporation of a long range telemetering radio of 50 watts output in a surface buoy secured to a large cargo type parachute drogue by 50 to 4000 meters of cable, have made it possible to follow these drogues by aircraft. Current flow patterns at various depths can now be realized which cover large areas of open ocean. Provisions have been made to include in the system sensors for temperature readings at depth, wind direction and velocity, and intermediate self contained current meters.

THE RADIO DROGUE SYSTEM

INTRODUCTION

It has long been the desire of physical oceanographers to obtain synoptic current measurements and associated data from the open ocean covering months and even years. Most of our present sampling techniques concerning current direction, velocity, temperature and salinity have been short term affairs involving single observations at widely spaced intervals in time and space. Concentrated efforts in small sections for relatively short periods of time have been the other alternative. None of these techniques approach long term surveys with the exception of Dr. William Richardson's work with anchored current meters between Cape Cod and Bermuda.

This report will discuss a new technique for tracking and recording of deep currents on a yearly basis over wide expanses of ocean. This project since early summer of 1961 has undergone many revisions since its concept and will probably undergo more in the future. During this interval three cruises originating from Woods Hole were undertaken for a total of five weeks of tests and trial current measurements. On June 14, 1962, the first three units were set out approximately 120 miles south of Bermuda. These were followed and checked for 10 days to assure their proper functioning then allowed to remain on station. Tracking and plotting operations by Woods Hole

Oceanographic Institution R4D aircraft were then done on a regular basis.

It is hoped (and indeed is showing) that the techniques used here will serve as a useful method of studying long term deep water circulation patterns and other phenomena.

APPROACH TO THE PROBLEM

In the past, drogues of many types have been used to follow currents. These have taken a wide variety of forms; canvas sea anchors, tin kites, parachutes, canvas current crosses, etc. Many of these efforts have been successful for limited applications. Costs of ships, personnel and the like have made it necessary that these measurements be of short duration and separated by many miles, months; even years.

With the advent of reliable, compact communications equipment, highly sensitive measuring devices and a new family of construction materials such as polyvinyl chloride, polyester foams, fiberglass and others, it became apparent that a system might be devised for a remote, self contained or telemetering type drogue that could withstand the rigors of its environment for long periods.

A pilot program of three drogues was placed in the Sargasso Sea this year and their positions determined by aircraft once every two weeks. Assuming an average speed of 12 cm/sec at 1000 meters

estimated that the three 1000 meter units would travel a total of about 6,000 miles in one year. Incorporated in the three units were current meters recording on 16 mm film for 50 seconds per hour. These current meters will not measure ordinary speed and direction but will give current shear and vector information.

The inclusion of temperature vs depth recorders with the current meters at the parachutes will give true depth of the measurement. Recorded temperature will give an indication as to the movement of the unit from one environment to another. Observations of the major ocean parameters and their fluctuations should enhance our sketchy knowledge in this area.

Instead of using valuable ship time for day to day tracking, aircraft have been substituted to locate the drogues over wide areas. To date, this method is proving satisfactory and it is hoped by this investigator that further expansion involving oceanographic aircraft will be considered in other areas of research. Considering the problems of large scale data acquisition, the advantages of this mode of transportation should be obvious.

GENERAL DESCRIPTION

On the surface a 13' PVC spar buoy, Figure 1, with two thousand pounds of added floatation supports the suspended cables

and equipment. In this buoy are batteries, radio receiver and transmitter with an output of approximately 50 watts and an operational life of one year.

Below this buoy, to the depth being investigated, are suspended telemetering thermometers, film recording current meters, temperature vs depth recorders, and at the end, a large cargo type parachute weighted with 100 - 300 pounds to keep it at the desired level. These nylon parachutes (up to 100 feet in diameter) are used in various combinations of sizes to obtain reasonable drag to resistance ratios for the depth at which they are set. The operational limits are from depths of 50 meters to 4,000 meters.

CONSTRUCTION OF SURFACE BUOY

The basic vehicle consists of 13 foot length of 8 inch diameter polyvinyl chloride seamless tube. At each end of this tube are welded 13 inch diameter flanges with "O" ring grooves, 12 equally spaced holes drilled and taped to coincide with the deck plate of the radio unit. Togive added strength to the top flange, four gussetts (one drilled to take 1/2" manila lines) have been added on the under side. These are spaced 90° apart. Tests proved the bottom flange, which supports the damper plate and sustains the entire weight of the suspended cables, to be too weak therefore 4 extra welded gussetts were added. In addition to these, 4 1/4" - 20 stainless steel bolts were inserted from the inside of the tube radially out into the flange. This modification has proven

satisfactory for strength. It will remain intact during a drop test of six feet and a buoy weight of 500 pounds striking the edge of the damper plate at about 45°. To seal off the bottom of the tube a 2 foot square 3/8" aluminum plate is bolted up against another "O" ring to form a water tight seal. This serves also as an electrical ground to sea water for the radio. On the outside center of this plate is welded an aluminum pad drilled to match two 1" PVC check bolts through which a 3/4" cadmium bolt has been inserted for an axle. See Figure 2. A teflon bushing with a stainless steel outer sleeve has been fitted around this axle and between the check blocks to take the load of the first shackle of the suspended underwater cable. This has proved very satisfactory under all conditions of stress. The Teflon bushing lubricated with sea water and protected from point compressions of the shackle by the stainless outer sleeve provides a non chafing flexible joint at this maximum motion point for many months. The PVC check blocks form a galvanic barrier between the steel cable and fittings and the aluminum damper plate.

FLOAT

The construction of the floatation pod finally evolved to a can shape four feet high and three feet in diameter. This is located eighteen inches from the top flange of the PVC radio case. A 2' 7" diameter by 3' 7" long core of ridged "foam-in-place" polyester foam (Nopco Lockfoam H-102) was poured in a masonite form imbedding two ridged

discs that are secured to the tube. This core, so fixed, will not work loose or shift on the tube. Overlaying the core a 2-1/2" thick blanket of flexible polyurathane "foam-in-place" plastic was poured into a 3' diameter by 4' long finish form. This flexible coat is quite tough and will not crack or weather even in the most severe environment. Its ability to absorb shocks both in shipboard handling and launching operations as well as in the water (collision, large seas, etc.) has greatly improved the overall performance of the buoy. Delicate electronic components housed in the case now stand a better chance of survival under this system as opposed to hard fiberglass or aluminum containers. Total buoyancy for the surface buoy, unloaded, equals about 2,290 pounds.

Future units will have incorporated in the floatation instrument wells for meteorological and surface phenomena sensors. These will be both telemetering and data storage types.

RADIO INSTRUMENTATION

The heart of the entire system is the locating and telemetering radio. For this a commercially available unit has been chosen. This unit was developed by Concord Controls Incorporated of Boston, Massachusetts as a cooperative venture with Woods Hole Oceanographic Institution over a period of two years or more. Here again an evolution of ideas and mechanics has progressed to a suitable design that is versatile and reliable.

Figure 3 shows a 40" frame with three plug in modules; transmitter (2398 KC and 50 watts output), receiver (3 mode operation) and time and switching unit containing code disc and identification number and relays for mode switching. Circuit diagrams for the transmitter receiver and timing and switching unit are found in Figures 4-5 and 6. Each of these modules are standard and interchangeable between buoys. The power is supplied from two 7.5 inch diameter by 36 inch long, 24 volt battery packs connected in parallel. With the receiver on stand-by position and transmissions held to 40 per month, the life of the unit is about one year. This figure cannot be accurately ascertained because of varying atmosphere noise conditions which impose fluctuations in receiver power drain on the batteries.

External tuning and adjustment controls are located on the radio top cap and sealed with PVC covers when not in use. Also located on the top surface of the suoy is the antenna mount and 13' whip antenna.

Upon interrogation of the buoy, a tone modulated RF carrier matched to the receiver frequency is transmitted. This can be done from shore, ship or aircraft. Frequency sensitive relays in the receiver switch on the transmitter in the desired mode of operation; code and identification or one of two data modes. A pre-set time delay shuts down the transmitter and the unit resets again for receiver operation. Data in mode 2 and 3 is transmitted by the use of frequency shift keying. Mode 2 also operated an external light beacon for night

time search by ship or aircraft.

The remainder of the surface buoy load consists of power cables, battery separators and 100 pounds of lead ballast located at the bottom of the tube. The addition of this ballast improved the vertical stability of the buoy under rough sea conditions. The reduction of the lateral swinging motion of the antenna prevented some of the minor de-tuning problems encountered when the loading coil on the whip closed the distance to the ground plane of the sea surface.

UNDERWATER CABLES AND EQUIPMENT

Suspended below the surface buoy down to the drogue chute are a varierty of sensing instruments. These presently cover temperature, stored and telemetered, relative current velocity and direction at intermediate levels between the buoy and the chute and the depth of these measurements. Work is underway to enlarge the scope of sampling to include in-situ salinity measurements. Whether this will be a self contained data storage instrument or a telemetering type has not as yet been ascertained. Connecting links for all instruments are 5/32", 7 x 7 stainless steel cables. Earlier models employed 1/4" polypropylene rope in an effort to take advantage of its flexibility and floating characteristics. This unfortunately, proved to be too much of a temptation for large sea creatures who habitually bit it in two. Because of this problem, stainless cable, even though harder to handle, was finally selected.

TELEMETERING THERMOMETER

A temperature transducer developed by Angelo J. Campella of H. B. Seiger Company and the personnel at W.H.O.I. (1960) has been used to obtain remote temperature readings at a constant depth. The signal from the thermistor bridge and oscillator takes the form of a square wave pulse keying the transmitter relay to frequency shift the carrier. This shift rate is proportioned to the temperature. An accuracy of .03°C and a range of 0°C to 30°C is possible depending, of course, on receiving conditions.

The connecting link between the transducer and the surface is currently a 100 meter length of Amagraph 4-H-O well logging cable. Work is about completed on a variation of this circuit which will increase the number of sensors to 10 spaced units down a maximum depth of 500 meters. These will automatically trip and reset in sequency when initiated by a triggering pulse from the interrogating station. In this manner a 500 meter temperature profile may be obtained on command.

CURRENT METER

This unit, developed by Dr. William Richardson of W.H.O.I. (1962) and now manufactured by Geodyne Corporation of Waltham, Massachusetts, is self contained and film recording. Only a small modification in the sample rate has been made. This rate is now 50 seconds of current velocity and direction once each hour for a period of about 300 days. After retrieving of the instrument, the film is ready

by photo scanning techniques and processed by computer in whatever form desired. Actual details of construction of the meter need not be discussed here. (Reference No. 62-6, W.H.O.I., W.S. Richardson 1962).

The placement of current meters in the suspended cable system is flexible, making possible the collection of data at any intermediate level down to the drogue chute. In addition, a self contained temperature-depth recorder is secured directly below a current meter to determine both the depth of measurement and the wire angle of the drogue cable. This recorder takes samples at the same rate as the current meter and is read in the same manner. When a current meter and temperature-depth recorder are located at the same level as the drogue chute, an accurate determination of both the depth of the chute and the slippage or efficiency of drogue can be made. These corrections are then applied to the final velocity and direction results.

PARACHUTE

The success in obtaining accurate observed flow data of deep currents with the drogue system depends primarily on the choice of the submerged member. After considering a number of possibilities, a surplus cargo type parachute was chosen for this purpose. They range in size from 64 feet to 100 feet in diameter and are constructed from heavy nylon cloth and braided line. When used singularly, a 64 foot chute gives about 3200 square feet of effective drag surface and the 100 foot model equals about 7800 square feet. Combinations up to 3 - 100'

chutes are used when the set depth is 4000 meters. Figure 7 gives the calculated area and drag ratios for typical drogue sets down to 4000 meters.

The weight of the smaller one in water equals about 16 pounds and the larger equals 44 pounds. Attachment of the chute to the cable is shown in Figure 8. The heavy duty chute shackle is secured to a 5" galvanized ring and this ring directly fixed to the weak link at the end of the suspended cable or the last temperature depth recorder. To keep the chute from rising in periods of stress on the surface float a 100 pound weight has been suspended on a 100 foot length of cable. This cable is also shackled into the ring. The weak link is an 18 inch piece of cable which breaks at 1000 pounds as opposed to 2600 pounds for the main cable. The function of the weak link is to drop both the chute and weight during the retrieving operations retaining the main cable and meters only. Any attempt to hoist 7800 square feet of nylon in water 3000 or more meters would take the better part of two days!

TRACKING PROCEDURE AND INSTRUMENTATION

To date a Navy R4D aircraft (DC-3) operated by W.H.O.I. has been employed to obtain fixes on each drogue. These overwater flights occur about every two weeks which leaves some room for adverse weather conditions and mechanical problems. In view of the working range of the buoy radios it would be possible to extend the time interval to four weeks and still locate the unit.

In practice, an audio null bearing is taken with a Bloodworth RDF receiver while about 300 miles from the nearest estimated drogue position. This bearing is chosen as a base course and additional bearing taken on other units in the area during the flight. In this manner cross bearings revealing the positions of any number of buoys within 300 miles is accomplished while flying directly only towards one. This buoy is triggered about every 50 miles to correct any small deviations of the flight path.

At approximately 100 miles away, a sharper, well defined null can be noted on the meter as well as a marked difference in the audio null. When close to 75 miles away the pace is stepped up to one transmission each five minutes until an appreciable increase in signal strength is noted on the meter. Again the triggering rate is increased to one every two minutes until the null is completely blocked out regardless of sensing loop direction. This indicates that the aircraft is within one or two miles of the buoy. At this time, the plane is turned and flown in an orbit and its position determined. It might be noted here that on several occasions a visual sighting on buoys has been made but usually this is not the case because of high altitude or adverse visability.

CONCLUSION

Four months of current measurements have been completed to date and the data are now available (Parker 1963). On the basis of this work there are some changes to be made but these are minor ones.

The following is a breakdown of the surface buoy components

and an evaluation of each. These observations are from two of the original three units deployed 120 miles south of Bermuda for about 126 days. The third unit is still at sea.

Unit	Comments	Action to be taken
1. Surface Float	a) a few goose barnacles on damper plate and foam floatation.	None
	b) no leaks in the PVC instrument case or damage to floatation.	None
	c) minimum corrosion above the water line and virtually none below. Aluminum 6061-T6 and stainless type 302 alloys showed no corrosion.	No change
	d) overall condition was good.	
2. Cable fittings	a) top most galvanized thimble (3/8") completely destroyed through corrosion.	Should be stainless.
	b) first large shackle (3/4") only slightly worn where contact with thimble was made.	None
	c) nicopress fittings on stainless cable showed minimal corrosion.	None
	d) teflon bearing and stainless sleeve (Fig. 2) show only .005" wear.	None
	e) PVC check blocks had some chafe marks on inside surfaces made by large shackle.	None
	f) galvanized axle bolt (3/4") slightly corroded but still in fair condition.	Change to stainless pin.

Unit	Comments	Action to be Taken
3. Radio Equipment	a) final output approximately 42 watts and range still 900 miles or more.	None
	b) approximately 700 transmissions sent by each buoy.	
	c) one switch knob loose.	Tightened
4. Cables	a) 5/32" stainless cable parted in two cases due to loops and unlaying of strands and eventual chafing of wires. No. 4 unit parted between 18 and 24 October 1962 just prior to pick up. No. 5 on or about August 3, 1962. The third, No. 6, was last seen intact and operational on 18 October 1962. Adverse weather conditions did not permit retrieving of this drogue.	Will use 3/8" 7 x 19 plastic core, stainless wire rope.
5. Batteries	a) voltages down to 20.0, 5.75, 2.95 from originals of 24, 6 and 3. Good for one more month's operation.	
	b) sharp edges of battery sheaths chafed inside of PVC buoy case.	File smooth.
6. Antenna	a) one slightly cracked but operational.	Re-design of antenna mast for greater strength.
	b) remaining two in good condition.	

ACKNOWLEDGEMENTS

I would like to thank all those who offered their time and encouragement for this project. The services of Mr. Robert Walden and the Electronics Laboratory here at Woods Hole Oceanographic Institution were invaluable for their assistance on the radio equipment. I would like to especially thank Captain David Casiles and his crew on the R/V CRAWFORD for all their help during the testing and setting operations and Captain Norman Gingrass and the crew of the R4D aircraft during the four months of flying involved in tracking the drogues.

The help of Concord Controls, Inc., and their permission to include the schematics for the radio units is greatly appreciated.

LIST OF FIGURES

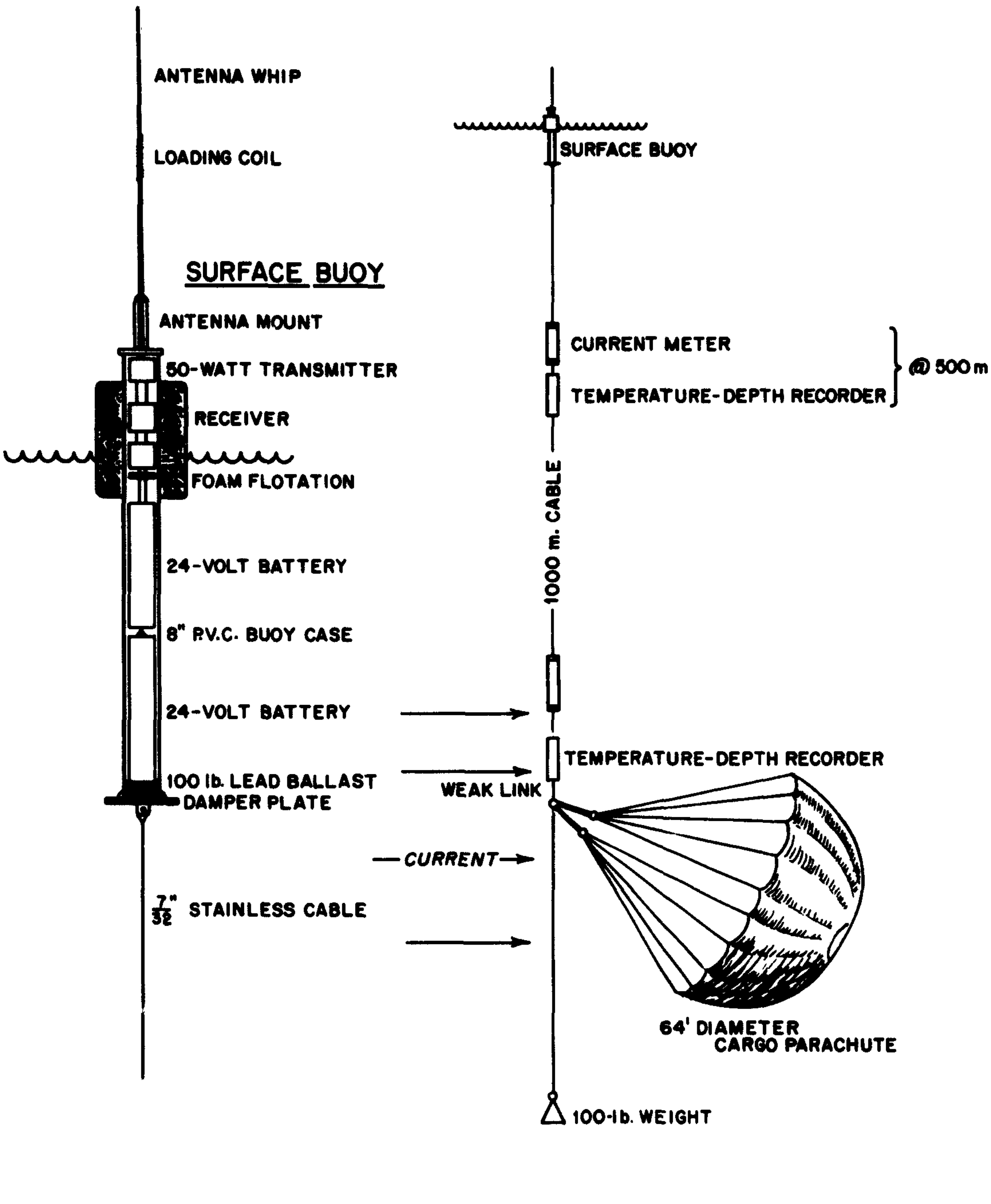

FIGURE 1. OVERALL DROGUE ASSEMBLY

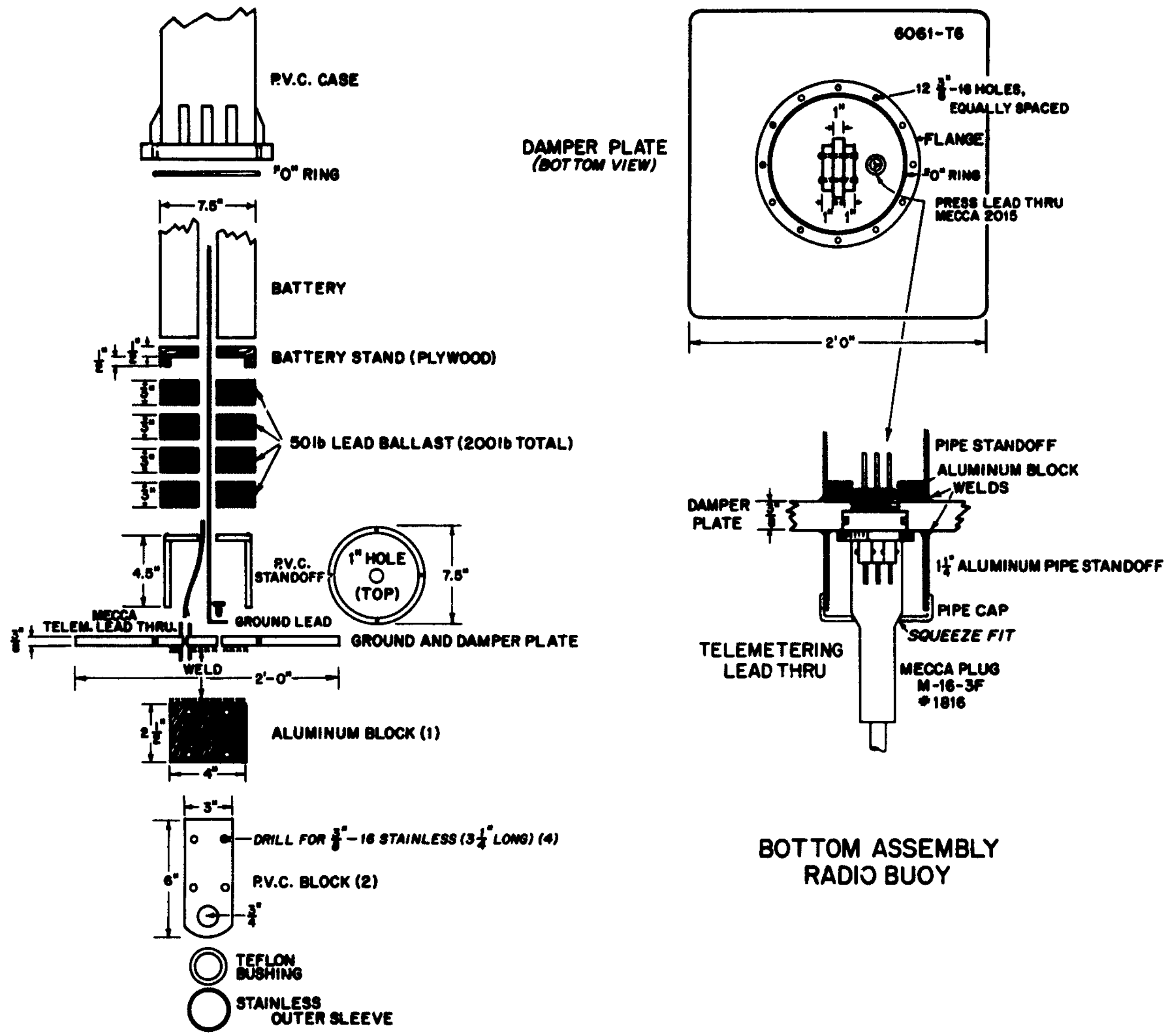

FIGURE 2. SUSPENSION AND BOTTOM ASSEMBLY

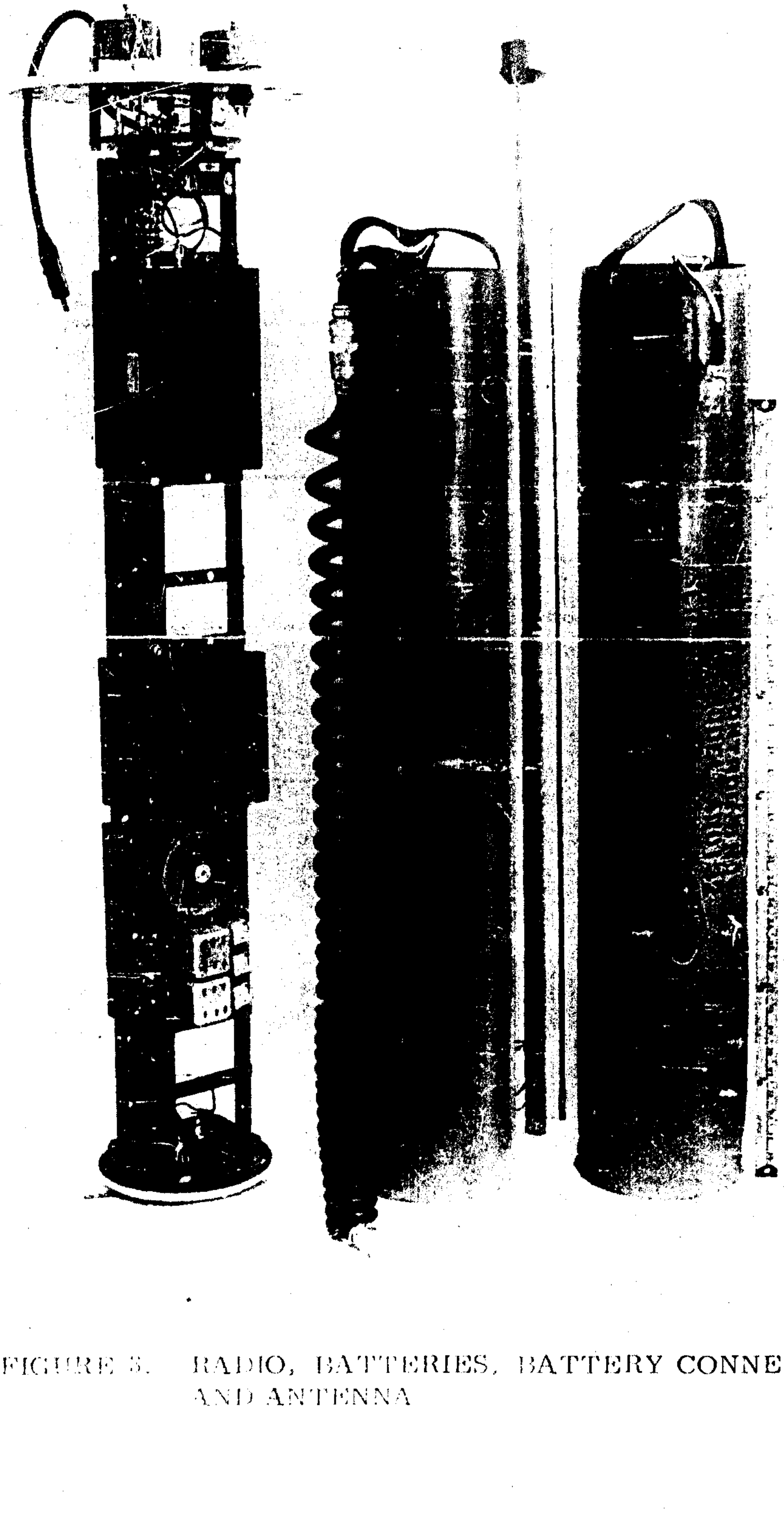

FIGURE 5. RADIO, BATTERIES, BATTERY CONNECTOR AND ANTENNA

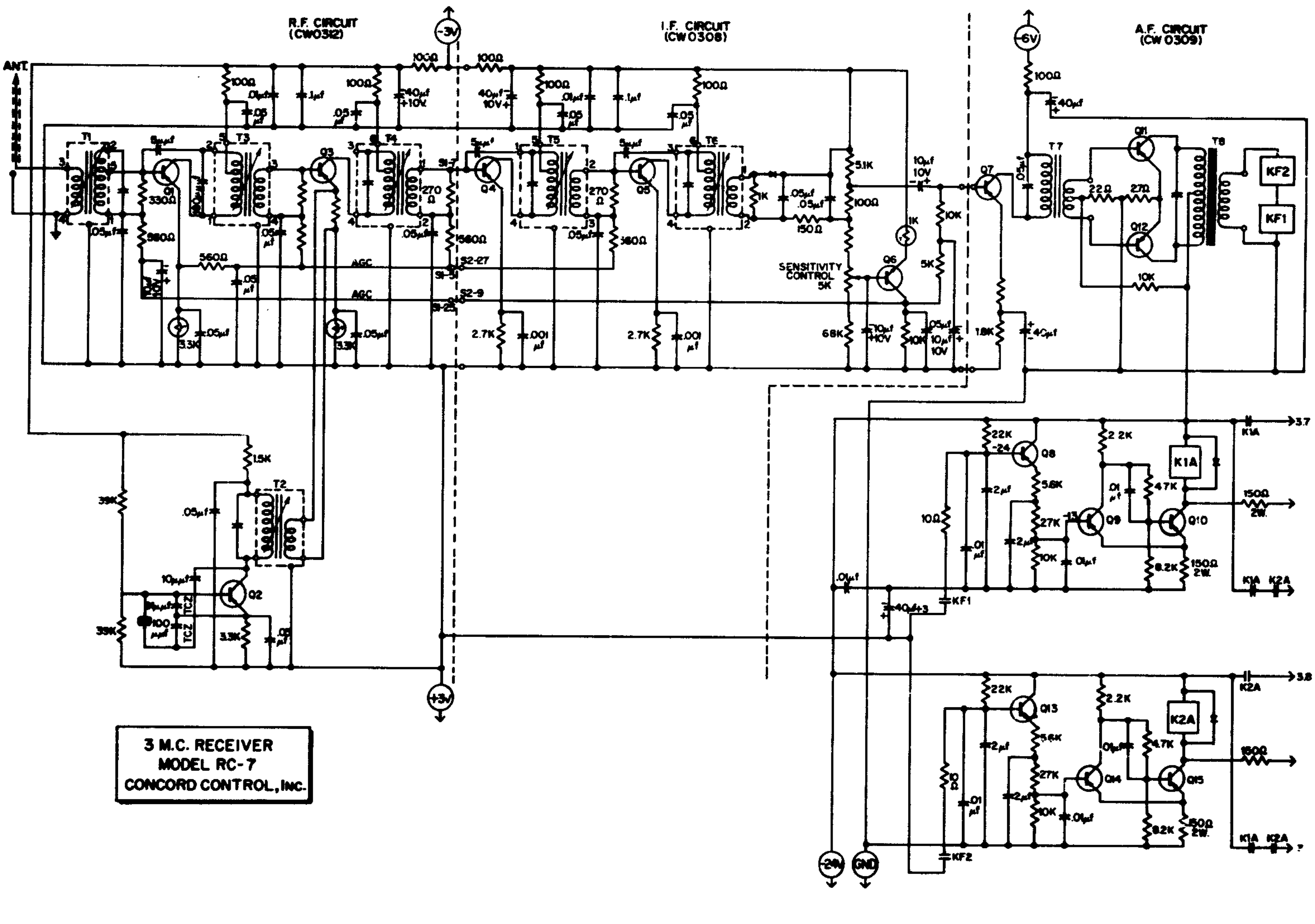

FIGURE 4. RECEIVER SCHEMATIC

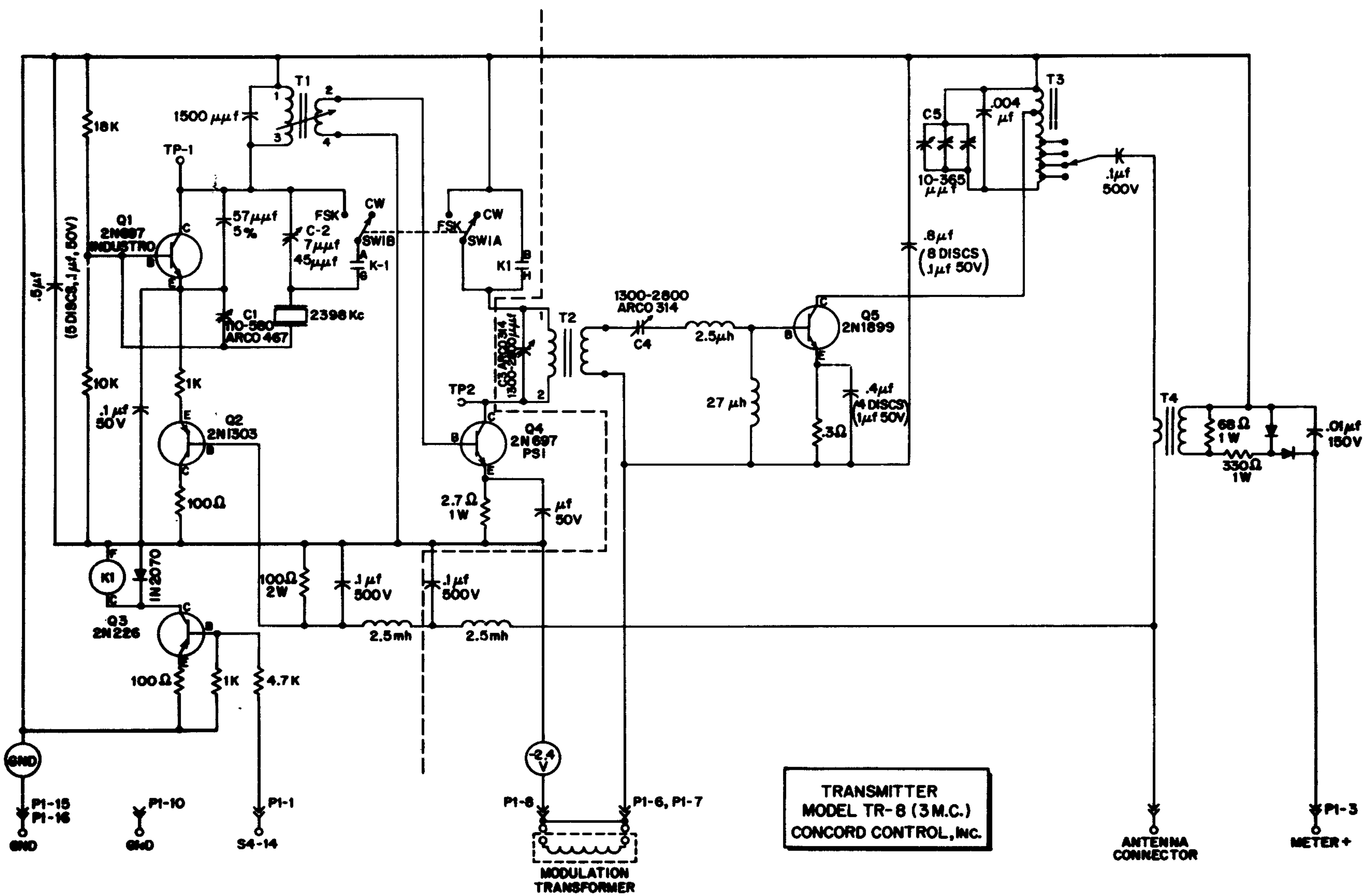

FIGURE 5. TRANSMITTER SCHEMATIC

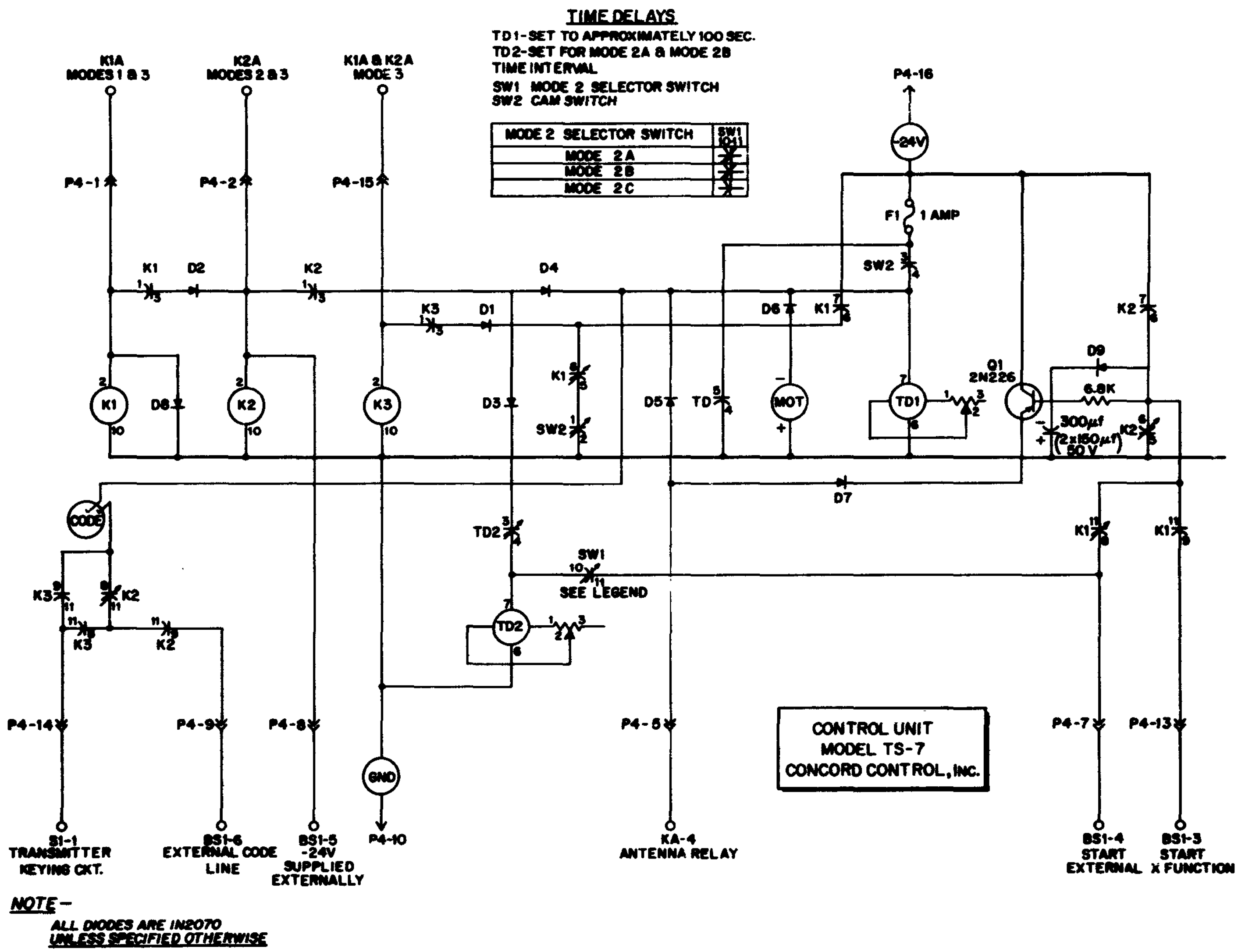

FIGURE 6. TIMING AND LOGIC UNIT SCHEMATIC

Parachute Depth	No. of Chutes & Diameter	Chute Area, Sq. Ft.	Surface Buoy Area	Total Instrument & Cable Area	Maximum Assumed Current Speeds	Average Lbs. Drag Chute	Maximum Opposed Lbs. Drag, Buoy, Cables; Inst.	Area Ratio Chute/Buoy, Cables, etc.	Drag Ratio Chute/Buoy, Cables, Etc.
Surface to	1-64'	3, 200	13. 5	. 5	1. 5 kts	13, 440	58. 85	175:1	228:1
1000 m	1-64'	3, 200	13. 7	5. 25	. 3 kts	1, 600	62. 08	169:1	25. 4:1
or	1-100'	7, 850	13. 7	5. 25	. 3 kts	3, 920	62. 08	414:1	63. 1:1
2000 m	2-64'	6, 400	14. 0	10. 02	. 25 kts	2, 560	65. 19	266:1	39. 3:1
or	2-100'	15, 700	14. 0	10. 02	. 25 kt	6, 290	65. 19	655:1	96. 5:1
3000 m	1-64'+								
and	1-100'	11, 050	14. 2	14. 79	. 20 kts	2, 210	66. 05	382:1	33. 4:1
or	2-100'	15, 700	14. 2	14. 79	. 20 kts	3, 140	66. 05	541:1	42. 5:1
4000 m	2-100'	15, 700	14. 5	18. 06	. 1 kt	785	66. 67	482:1	11. 8:1
or	3-100'	23, 550	14. 5	18. 06	. 1 kt	1, 178	66. 67	725:1	17. 8:1
5000 m	3-100'	23, 550	15. 0	22. 33	. 07 kt	235	69. 73	630:1	3. 4:1
or	4-100'	31, 400	15. 0	22. 33	. 07 kt	314	69. 73	840:1	4. 5:1

FIGURE 7. CALCULATED DRAG RATIO AND DROGUE EFFICIENCY

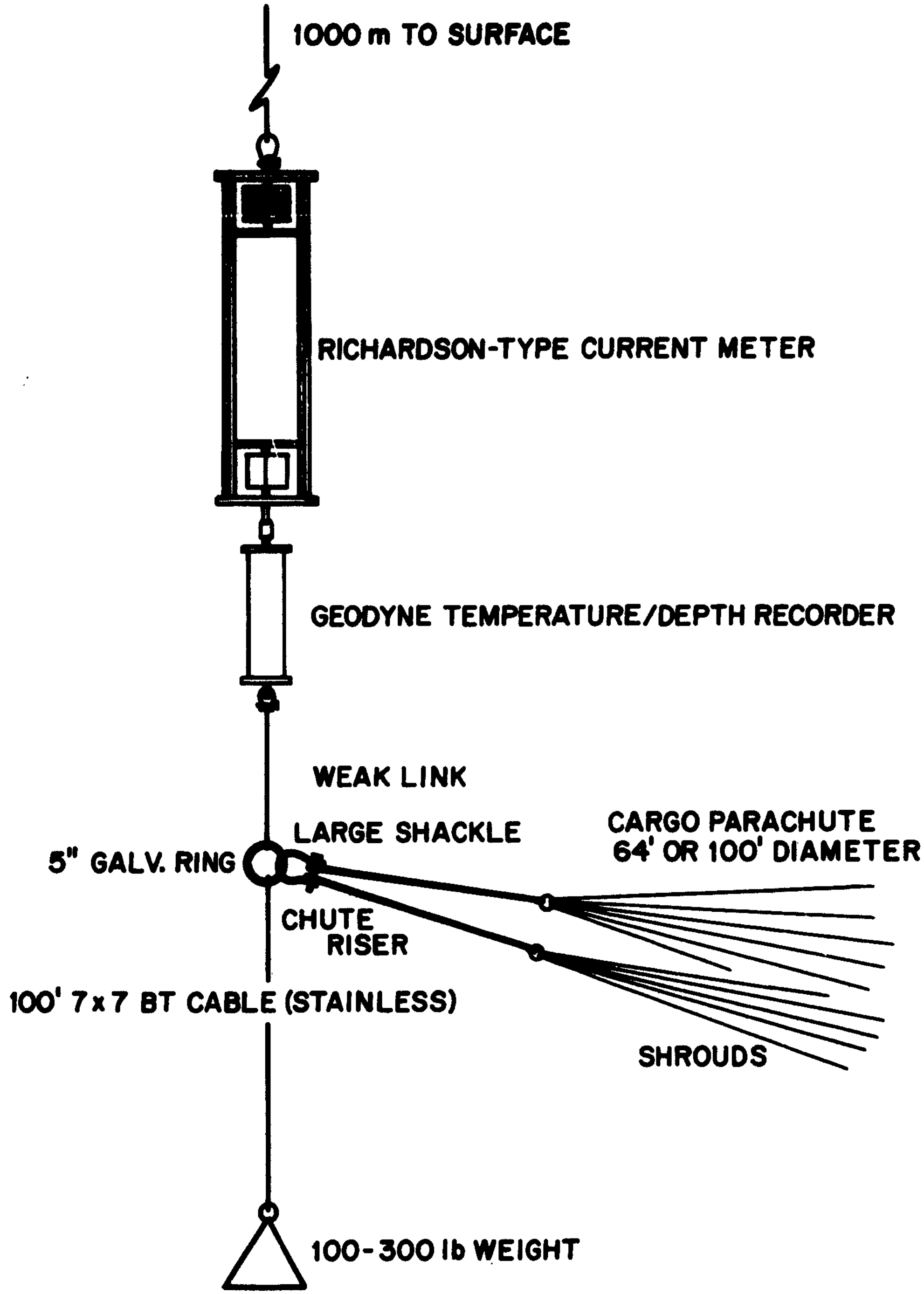

FIGURE 8. CARGO PARACHUTE ATTACHMENT

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The Radio Drogue System, (U), by Charles E. Parker, 16 p, 8 figs., March 1963

Unclassified

During the period between June 1961 and June 1962, a successful system was developed at Woods Hole Oceanographic Institution for directly measuring deep ocean currents covering many months of time. The incorporation of a long range telemetering radio of 50 watts output in a surface buoy secured to a large cargo type parachute drogue by 50 to 4000 meters of cable, have made it possible to follow these drogues by aircraft. Current flow patterns at various depths can now be realized which cover large areas of open ocean. Provisions have been made to include in the system sensors for temperature readings at depth, wind direction and velocity, and intermediate self contained current meters.

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3. Telemetering Thermometer
4. Current Meter Use
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